Using On-Farm Measures to Predict Eating Time and Feed Intake in Dairy Cattle

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Introduction

The modern dairy cow has very high nutrient demands to achieve and maintain the genetic potential for milk production. Intake is one of the most important variables affecting animal performance and as such, is one of the single most significant measures made on a dairy farm (Waldo and Jorgensen, 1981; Roseler et al., 1997). Since intake is highly related to milk production, prediction equations have been created for intake, more specifically dry matter intake (DMI), and one of the most commonly used is the Dairy NRC equation (2001) which includes milk production, body weight, and stage of lactation to predict DMI. Using animal measurements has been the standard approach for creating DMI predictions, but the environment the cow is living in can also play a significant role.

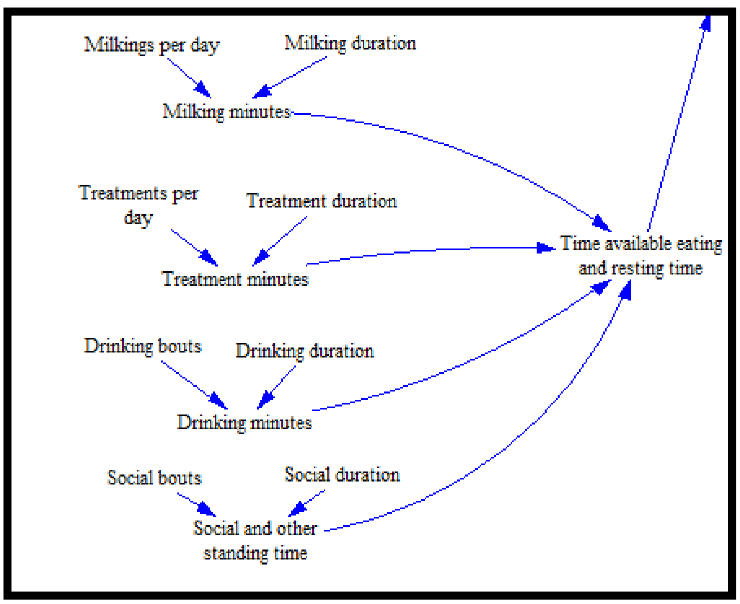

Figure 1. Schematic of time budget for management model.

A major portion of the daily time budget for the modern dairy cow is spent lying down, around 660 to 720 minutes on average, and a second large time requirement is time spent eating, around 300 minutes (Grant, 2004). The management decisions we make, and their consequences, may impede either lying or eating time and can affect DMI such as stocking density, feed frequency, feed availability, lameness, or heat stress (Phillips and Rind, 2001; DeVries et al., 2005; Mantysaari et al., 2006; Cook et al., 2007; Norring et al., 2014; Grant, 2015). Overstocking increases eating rate, displacements at the feed bunk, lameness, and standing time (Grant, 2015). In some studies, increasing the number of daily feedings has increased the time spent eating and decreased lying time (Phillips and Rind, 2001; DeVries et al., 2005; Mantysaari et al., 2006), whereas lameness has been shown to decrease eating time and increase eating rate (Norring et al., 2014). Heat stress can cause a decrease in DMI, milk yield, and lying time (Cook et al., 2007). These management factors affect the cow's ability to prioritize rest and intake, which is necessary for health and high levels of productivity.

Recently we have focused on trying to quantify and predict the effects of management decisions on DMI using mathematical modeling. The first step was to build the time budget for the dairy cow to include time spent milking, receiving treatments, drinking, and social and other standing time (Figure 1). These were then added up and subtracted from 1440 minutes to get time available for lying and eating. The lying time was calculated by subtracting eating time from the time available for lying and eating (Figure 2). The lying time was then used in the prediction of fat-corrected milk (FCM) to calculate DMI using the Dairy NRC (2001) equation (Figure 2). The weakness of the time budget section is the ability to measure eating and lying time on-farm, and the intake section is dependent on an accurate DMI and milk yield. There is a need to accurately predict eating time, DMI, and milk yield to help increase the accuracy of the management model.

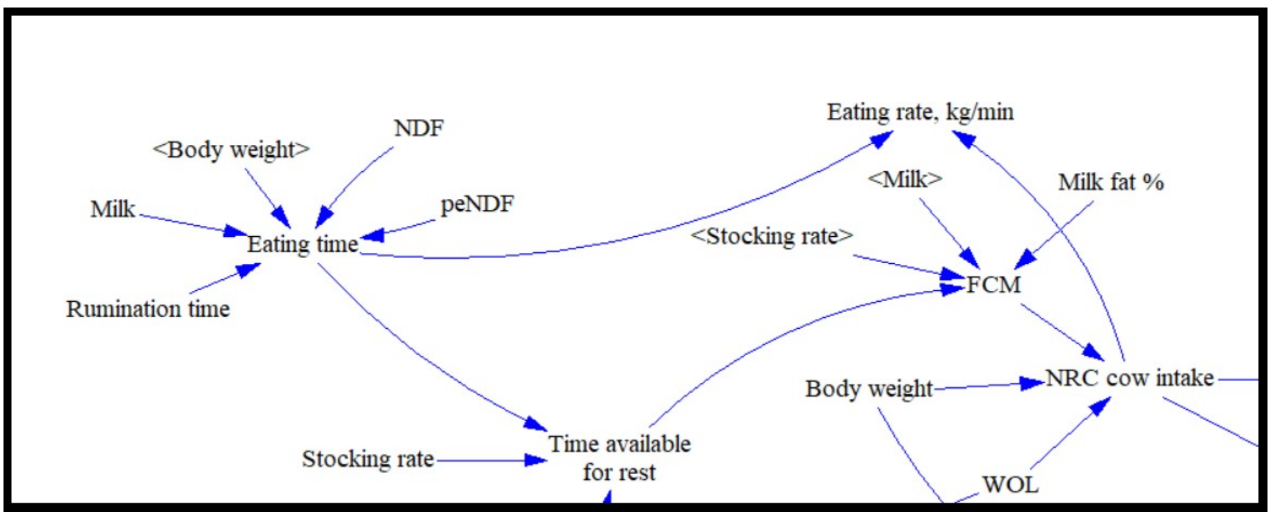

Figure 2. Schematic of eating and resting time and intake layout for management model.

Miner Institute Study:
Predicting Eating Time, DMI and Milk Yield

To begin addressing the issues above, we used 6 studies of high producing dairy cows fed high and low forage diets containing different sources of forages and varying forage particle sizes to create prediction equations for eating time, DMI, and milk yield using common on-farm measures (Kononoff et al., 2003; Cotanch et al., 2014; Miller et al., 2017; Smith et al., 2018; Coons et al., 2019; Miller et al., 2019). The on-farm measures we selected were neutral detergent fiber (NDF) content, physically effective NDF (peNDF), milk yield, body weight, and rumination. We conducted multiple linear regression (MLR), and partial least squares (PLS) on 20 treatment means from our database. Data were analyzed using Reg and PLS procedures using SAS (version 9.4).

Table 1. Regression statistics for linear prediction equations for eating time, DMI, and milk yield.

Outcome variable	Predictor variable	Partial R-square	Model R-square	VIF
Eating time, min/d	NDF content, % of DM	0.252	0.83	5.5
	peNDF, % of DM	0.045		5.5
	Rumination time, min/d	0.091		4.3
	Body weight, kg	0.069		2.1
	Milk yield, kg/d	0.374		5.4
DMI, kg/d	NDF content, % of DM	0.219	0.69	5.5
	peNDF, % of DM	0.026		5.5
	Rumination time, min/d	0.099		4.3
	Body weight, kg	0.011		2.1
	Milk yield, kg/d	0.334		5.4
Milk yield, kg/d	NDF content, % of DM	0.301	0.82	3.6
	peNDF, % of DM	0.500		3.9
	Rumination time, min/d	0.003		4.1
	Body weight, kg	0.011		1.9

The MLR analysis to predict eating time accounted for 83% of the variance using NDF content, peNDF, rumination time, body weight, and milk yield (Table 1). The MLR analysis to predict DMI accounted for 69% of the variance using NDF content, peNDF, rumination time, body weight, and milk yield. A large proportion of the accounted variance for eating time and DMI was from the milk yield and NDF content with 63% and 55%, respectively. The MLR analysis to predict milk yield accounted for 82% of the variance using NDF content, peNDF, rumination time, and body weight. The NDF content and peNDF accounted for the largest proportion of accounted variance in milk yield with 80%.

Partial Least Squares analysis accounted for 80.1% of the between-treatment variance in eating time, and 4 traits had a variable of importance in projection (VIP) score > 0.9, which included NDF content, peNDF, rumination time, and body weight (Table 2). The PLS analysis accounted for 63.5% of the between-treatment variance in DMI, and 3 traits had a VIP score > 0.9, which included NDF content, peNDF, and milk yield. The PLS analysis accounted for 75.9% of the between-treatment variance in milk yield, and 2 traits had a VIP score > 0.9, which included NDF content and peNDF.

Table 2. Variable of importance in projection (VIP) scores and accounted variance using partial least squares for predicting eating time, DMI, and milk yield.

Outcome variable	Predictor variable	VIP	Accounted variance
Eating time, min/d	NDF content, % of DM	0.92	80.1

	peNDF, % of DM	0.95	
	Rumination time, min/d	1.50	
	Body weight, kg	0.90	
	Milk yield, kg/d	0.46	
DMI, kg/d	NDF content, % of DM	0.92	63.5
	peNDF, % of DM	1.01	
	Rumination time, min/d	0.74	
	Body weight, kg	0.66	
	Milk yield, kg/d	1.47	
Milk yield, kg/d	NDF content, % of DM	1.04	75.9
	peNDF, % of DM	1.52	
	Rumination time, min/d	0.73	
	Body weight, kg	0.29	

Table 3. The summary statistics of 13 published studies with 50 treatments using lactating dairy cows.

Item	Mean	SD	Minimum	Maximum
DMI, kg/d	24.9	2.6	20.5	31.1
Milk yield, kg/d	37.2	6.4	26.2	46.4
Eating time, min/d	228	28	173	318
Rumination time, min/d	469	72	236	564
Body weight, kg	668	47	567	753
NDF content, % of DM	32.6	2.8	27.3	37.5
peNDF, % of DM	25.2	4.6	15.2	34.0

To test the predictive ability of the equations from MLR and PLS we compiled 13 published studies with 50 treatments using lactating dairy cows that included DMI, milk yield, eating time, rumination time, body weight, NDF content and peNDF (Table 3; Grant et al., 1990; Beauchemin et al., 2003; Yansari, et al., 2004; Yang et al., 2006, Yang et al., 2007; Yang et al., 2009; Hart et al., 2013; Hart et al., 2014; Farmer et al., 2014; Campbell et al., 2015; Crossley et al., 2017; Campbell et al., 2017; Crossley et al., 2018). The summary statistics of the studies are presented in Table 3. The mean absolute error (MAE) of eating time, DMI, and milk yield using prediction equations from MLR and PLS using 13 published studies with 50 treatments split into different groups (all, multiparous, primiparous, and mixed) are presented in Table 4. For eating time, the PLS had a lower MAE compared to MLR with the best predictive ability for the multiparous and mixed groups of 35.4 and 35.1 min/d, respectively. Whereas for DMI, the MLR had a lower MAE compared to PLS with the best predictive ability for the primiparous group of 1.4 kg/d. For milk yield, the PLS had a lower MAE compared to MLR with the best predictive ability for the primiparous and mixed group of 4.6 kg/d. The prediction equations can moderately predict eating time, DMI, and milk yield of lactating dairy cows.

Table 4. Mean absolute error (MAE) of eating time, DMI, and milk yield using prediction equations from multiple linear regression (MLR) and partial least squares (PLS) on 13 published studies with 50 treatments.

MAE	Eating time, min/d		DMI, kg/d		Milk yield, kg/d	
Cows	MLR	PLS	MLR	PLS	MLR	PLS
All	57.8	40.2	1.7	2.7	9.1	7.4
Multiparous	56.4	35.4	1.7	3.0	11.2	9.1
Primiparous	100.2	70.3	1.4	2.7	8.4	4.6
Mixed	36.8	35.1	1.6	1.8	3.9	4.6

Summary and Perspectives

This project evaluated the predictive capability of using on-farm measures to predict eating time, DMI, and milk yield to be used in a mathematical model to account for management effects on DMI. We were able to moderately predict using NDF content, peNDF, rumination time, body weight, and milk yield. The greater accuracy of eating time, DMI, and milk yield will increase the sensitivity of the model to management effects. As the development of the model continues, the long term goals will be to build a larger dataset for creating prediction equations, adding additional management decisions to the model, and using on-farm observations to validate the model. Though this is in the early stages of development, there is promise to create a tool to help identify areas of opportunity to optimize the dairy cow's time budget to maximize health and performance.

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